R&D Subsidies and Firm-Level Productivity: Evidence from France

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R&D SUBSIDIES AND FIRM-LEVEL PRODUCTIVITY: THEORY AND EVIDENCE FROM FRANCE

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Abstract

This paper investigates a theoretical and empirical model to provide a new insight into the relationship between R&D subsidies and firm-level productivity. The empirical analysis evaluates the productivity of firms involved in a European programme of public R&D subsidies called Eureka. The findings suggest that the Eureka firms experience on average productivity gains towards the end of the four-year subsidy period. However, the average increase in productivity hides substantial firm heterogeneity. Namely, lowly productive firms gain more from the Eureka R&D subsidies than highly productive firms. The empirical analysis is conducted across industries by using propensity score matching and a difference-in-differences estimation method. The theoretical model explores the linkage between an R&D subsidy and the speed at which a subsidized firm adopts a new technology. It is shown that such a firm adopts the new technology faster. This is due to R&D subsidy decreases the fixed cost of adopting the new technology. But it is also due to R&D spillovers which decrease the marginal cost of production. Furthermore, the lowly productive firm characterized by a high marginal cost adopts the new technology faster than a highly productive firm.

Keywords: R&D subsidies, Research Joint Venture, Total Factors Productivity and Firm Heterogeneity.

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1 Introduction

Public R&D subsidies are commonly implemented to stimulate innovations and economic growth. R&D subsidies are justified for two main reasons. The first is because firms face important R&D expenditure constraints and the second is due to R&D spillover effects. Indeed, knowledge is a public good whose social returns are higher than private returns. The R&D activities of a firm generate spillovers which affect positively the activities of others firms without payment (Jaffe, 1986). The firms benefiting from R&D spillovers tend to invest less in R&D (Leahy & Neary, 1997). Therefore, subsidies can be an important tool to make these firms invest in more R&D.

The efficiency of R&D subsidies is debatable. In particular, some argue that given the fact that authorities do not have the ability to identify firms that need R&D subsidies, firms develop an opportunistic behavior. Namely it can be that firms who could undertake R&D by themselves ask for subsidies, and therefore their private R&D expenditures are fully "crowded out" by public subsidies. This "crowding-out effect" decreases the efficiency of the R&D subsidies. The efficiency of R&D subsidies is also debatable because it might be that the influence of pressure groups affects the selection of the subsidized firms (Baldwin & Robert-Nicoud, 2007). Moreover, other add that the choice of subsidized firms depends on political ambitions of the government. It is likely that the government selects the subsidized firms more on the basis of their constituency rather than on the quality of the project (Wallsten, 2000).

This paper aims at filling the gap in what is presently known about the link between R&D subsidies and firm performance. Previous literature has mainly studied the average effect of R&D subsidies on firm performance. Nevertheless, the effect of subsidies on heterogeneous firms has never been investigated. Firm heterogeneity has been pointed out in the trade literature as being a key issue to better understand firm performance and structure (Bernard & Jensen, 1995). The main contribution of this paper is thus to propose both a theoretical and empirical model to investigate the effect of R&D subsidies on namely the productivity of heterogeneous firms.

Theoretically, we develop a model that extends the model of Miyagiwa and Ohno (1995) to examine whether a subsidy for collaborative R&D increases the profit gain that a "laggard firm" gets from innovation. Such a subsidy decreases the innovation cost and creates spillovers. It is found that the "laggard firm" speeds up technology adoption and becomes more productive. Considering firm heterogeneity (Konings & Vandenbussche, 2007), the model predicts that a subsidized firm adopts the new technology faster if it is lowly productive than if it were highly productive.

We also develop an empirical model that lends support to the theory. In the model, we evaluates the Eureka program, a European programme of public subsidies for collaborative R&D. We investigate the role of R&D subsidies on productivity. We also explore the role of subsidies on other firm performance measures like employment, capital and R&D expenditures. The Eureka programme subsidizes mainly firms, research centers and universities in 38 countries. Although various EU members are involved in the Eureka program, we focus on France.[1] Since the creation of Eureka 26 years ago, France has invested around 5 billions in the programme.

Our empirical results suggest that at the end of the four-year Eureka research, subsidized firms show on average a higher Total Factor Productivity (TFP) relative to the control group. As it will be explained later, our control group consists of firms that have the same characteristics but do not receive any funding from Eureka. Our results also suggest that firm heterogeneity is a key feature. Less efficient firms experience higher TFP improvements. On the other hand, firms that are close to the technological frontier become relatively less productive compared to the control group. Moreover, our results suggest that the average subsidized firm has a disadvantage in wage growth rate relative to the control group. Little evidence is found however on the relationship that could exist between R&D subsidies and employment, capital, R&D expenditures and credit constraints.

As mentioned above, the paper mainly contributes by addressing heterogeneity across subsidized firms. The paper also differs from the previous literature on public expenditures in at least two other ways. First, we control for two types of endogeneity. On one hand, it is likely that the firms conducting R&D have a higher likelihood to be selected. We account for this endogeneity by performing propensity score matching. We also correct autocorrelation in the difference-in-differences (DD) model on panel data.[2] On the other hand, the selection of subsidized firms can be endogenous because the selection might be linked to national rules. Indeed, national authorities select the Eureka firms in specific areas and industries, so we have to set additional requirements on matching to control for the location and industry.

[1] For example in 2006, France financed 11% (2, 667 millions) of all R&D expenditures carried out by French firms. The French gross domestic R&D expenditures is worth 37.9 billions in 2006 of which 25% are financed by the government. See the National profile of France (section Research Funding System) on the European Commission website: http://cordis.europa.eu/erawatch.

[2] See Baltagi and Wu (1999), Martin et al. (2008) and Konings and Vandenbussche (2008)

This treatment will decrease endogeneity and increase the efficiency of our matching. Second, the Eureka programme has received little attention until now due to a lack of data. This paper is one of the first to investigate the effect of the Eureka R&D subsidies on firm productivity.[3] We work with a unique database provided by Eureka on French firms joining its programme. Other firm data such as added value, exports and R&D expenditures were obtained using the Amadeus database on the firms' balance sheets.[4]

The rest of the paper proceeds as follows. Section 2 presents a theoretical model on the R&D subsidies and the speed of the technology adoption. Section 3 discusses the Eureka programme and its design. Section 4 describes the data and explains the empirical methodology. Section 5 explores the characteristics of the subsidized firms. Section 6 provides the results and robustness checks regarding the relationship between the Eureka R&D subsidies and the performance of the French firms. In sections 7 and 8, we open a discussion about our results and we draw conclusions from the study.

2 Theoretical motivation: R&D subsidies and speed of technology adoption

Our theoretical model gives a motivation for the subsidized R&D conducted within a research joint venture. Two cases are studied. The first case focuses on the spillovers coming from the collaboration whereas the second case focuses on the R&D subsidy, i.e. the subsidy that decreases the fixed cost of the technology adoption. In both cases, it is found that the optimal timing of the technology adoption speeds up because the firm decreasing its marginal costs becomes more productive. It is straightforward to see that the combination of both cases, i.e a subsidy for collaborative R&D, speeds up more the optimal timing even more. It is also found that firm heterogeneity matters.

There are two firms in the theoretical setting: one efficient firm and a "laggard firm" which attempts to narrow the technology gap. Assume a dynamic Cournot duopoly over a continuous time t with $t \in [0; \infty)$. In the dynamic Cournot game, a "laggard firm" competes with an efficient firm who has already adopted the latest technology available at $t = 0$. A university is added to the model. In order to narrow the technology gap, the "laggard firm" forms a research joint venture with this university or it asks for a R&D

[3] See also Benfratello and Sembenelli (2002).

[4] We focus on France due to the good quality of the Amadeus. For France, Amadeus is a census. It is not the case for the other EU countries.

subsidy.

The parameter θ describing the technology efficiency is continuous: $\theta \in [0; \infty)$. The two firms diverge in terms of marginal costs of production. The efficient firm has marginal costs of production equal to 0. The other firm is technologically lagged and operates at higher marginal costs of production given by $c_{\bar{\theta}}$, where $c_{\bar{\theta}} > 0$.

The adoption of the new technology is modeled by a reduction in the marginal costs. Here, we consider that this reduction in the marginal costs always corresponds to an increase in productivity. After the adoption of the new technology, the "laggard firm" operates at lower marginal costs denoted $c_{\underline{\theta}}$ and becomes more productive. The adoption of the new technology by the "laggard firm" at time t comes at a one-time fixed cost denoted $k(t)$. It is assumed that the fixed cost of the technology adoption declines over time because of ongoing R&D activity, i.e. $k^{'}(t) < 0$. It is also assumed that the rate of decline slows down over time, i.e. $k^{''}(t) > 0$. Furthermore, there is no uncertainty concerning the outcome of the R&D that cannot be unsuccessful.

2.1 Case one: R&D collaboration

In this first case, the "laggard firm" decides to form a research joint venture with a university in order to benefit from its knowledge throughout R&D spillovers. It is shown that spillovers flowing from the university to the "laggard firm" decrease directly its marginal costs (d'Aspremont & Jacquemin, 1988). Assume that the collaborative R&D is conducted from $t = 0$ through the adoption of the new technology at time t^*. The "laggard firm" finds the optimal timing of the technology adoption t^* balancing the innovation costs and the no innovation costs in each period t. Its intertemporal profit is the following:

$$\int_0^{t^*} e^{-rt} \underline{\pi} dt + \int_{t^*}^{\infty} e^{-rt} \overline{\pi} dt - e^{-rt} k(t) \tag{1}$$

where r is the given interest rate, $\underline{\pi}$ and $\bar{\pi}$ are the profit before and after the technology adoption. Hence, the two integrals are the discounted present sums of profit before and after adoption. The last term represents the discounted present value of the new technology fixed cost.

Assuming an interior solution, the optimal date of innovation t^* when the firm forms a research joint venture is given by the following first order condition:

$$rk(t) - k'(t) = \overline{\pi}(c_{\underline{\theta}}) - \underline{\pi}(c_{\bar{\theta}}) \tag{2}$$

This equilibrium condition (equation (2)) as well as the intertemporal profit of the firm (equation (1)) are derived by Miyagiwa and Ohno (1995). Equation (2) shows that at the optimal time t^* the marginal cost of adopting the new technology is equal to the benefit of the new technology. The left-hand side gives the marginal cost of the technology adoption. By waiting one additional period, the firm can invest elsewhere $k(t)$ on the market and earns $rk(t)$. In addition, postponing adoption lowers the adoption costs by $-k'(t)$. The right-hand side represents the value of technology, i.e. the profit gain of adopting the technology at time t.[5] Two corner solutions can emerge. First, the "laggard firm" can master immediately the new technology if its benefit is larger than its marginal cost. Next, if the benefit is less than its marginal cost for all periods t, the "laggard firm" never adopts the new technology (Boucekkine *et al.*; 2004).

The profit gain of the "laggard firm" is larger if it forms a research joint venture as shown in the following equation:

$$\overline{\pi}(c_{\underline{\theta}}) - \underline{\pi}(c_{\bar{\theta}}) < \overline{\pi}(c_{\underline{\theta}} - \delta) - \bar{\pi}(c_{\underline{\theta}}) \tag{3}$$

where δ denotes the decrease in the firm's marginal costs attributed to the R&D spillovers. The right-hand side and the left-hand side give respectively the profit gain with and without the R&D spillovers. The gain is larger with the R&D spillovers because the decrease in the initial marginal costs $c_{\underline{\theta}}$ is more important. The technology financed by the firm's private R&D expenditures decreases $c_{\bar{\theta}}$ that becomes $c_{\underline{\theta}}$. Furthermore, the research joint venture creates R&D spillovers that decrease the marginal costs by $-\delta$.

Figure 1 depicts the profit gain associated with the R&D spillovers. The horizontal line representing the time-invariant value of technology (profit gain) moves up. The downward sloped marginal cost of the new technology is unchanged. The initial optimal timing of adopting t_1 decreases and becomes t_2.

[Figure 1 about here]

2.2 Case two: R&D subsidy

In the second case, the "laggard firm" gets an R&D subsidy. Here, an R&D subsidy rate s is set in the firm's profit equation as well as in the first order

[5] Assuming that $k'(t) < 0$ and $k''(t) > 0$ guaranties a maximization of the profit.

condition (equations (1) and (2)). The intertemporal profit of the subsidized firm becomes:

$$\int_0^{t^*} e^{-rt}\underline{\pi}dt + \int_{t^*}^{\infty} e^{-rt}\overline{\pi}dt - e^{-rt}(1-s)k(t) \tag{4}$$

The last term is the discounted present value of the new technology's net fixed cost. The optimal switching time t^* is derived from the following first order condition:

$$r(1-s)k(t) - k'(t) = \overline{\pi}(c_{\underline{\theta}}) - \underline{\pi}(c_{\bar{\theta}}) \tag{5}$$

Figure 2 depicts the above first order conditions. Comparing equations (2) and (5), we see that the R&D subsidy speeds up the technology adoption since there is a shift to the left of the curve representing the marginal costs of the new technology. The horizontal line representing the time-invariant value of technology (profit gain) remains unchanged. The initial optimal timing of adopting t_1 decreases and becomes t_2. It is simple to show that a subsidy for collaborative R&D speeds up more the optimal timing than a single research joint venture or R&D subsidy does.

[Figure 2 about here]

2.3 Heterogeneity in marginal costs

Here, we allow firm heterogeneity in marginal costs (Konings and Vandenbussche (2007)). In particular, the "laggard firm" can have high or low marginal costs and we assume the marginal costs is a continuous variable. From our empirical results, we consider that the subsidised innovation has a heterogeneous impact on marginal costs since a "laggard firm" has more space to innovate. Hence, in both studied cases, a "laggard firm" narrows the technology gap faster. Its profit gain after the switch to the new technology is higher than if it has low costs:

$$\frac{\partial(\overline{\pi}(c_{\bar{\theta}}) - \underline{\pi}(c_{\underline{\theta}}))}{\partial c_{\underline{\theta}}} > 0$$

Using the assumption on the heterogeneity in costs, in both cases it is straightforward to show graphically the heterogeneous impact on the profit gain as depicted Figures $3-4$. The "laggard firm" adopts earlier the new technology if it has high costs than if it has low costs. After the innovation, the timing moves from t_1^* to t_3^* if the firm has high costs. It moves from t_1^* to t_2^* if the firm has low costs.

The theoretical model allowing heterogeneity can also be applied to a setting without collaboration and R&D subsidy. In this setting, the efficient firm still adopts the latest technology at time $t^* = 0$. The "laggard firm" adopts at time $t^* \in [0, +\infty)$. Figure 4 shows, for instance, that a firm with high costs gets a larger profit gain after the switch to the new technology. The initial optimal timing t_1^* becomes t_4^*. If the "laggard firm" has low costs, its new optimal timing is located between t_1^* and t_4^*.

[Figure $3 - 4$ about here]

In the theoretical model on the technology adoption of a "laggard firm", a R&D collaboration as well as a R&D subsidy speed up the technology adoption and allow the firm to operate with lower marginal costs. Considering firm heterogeneity in marginal costs, the results suggest that the "laggard firm" can narrow the technology gap faster if it has high costs. The model provides a theoretical motivation for R&D subsidies and then for the design of the Eureka program. However, such a programme for commercial R&D can be less profitable for the society if the projects associated with expected high private profits are subsidized. This issue is discussed it the following part.

3 The Eureka programme

3.1 A programme for collaborative R&D

The Eureka programme was launched in 1985 as a tool of European innovation policy, including the EU Framework Programmes for research and technological development. These programmes focus on fundamental research. Designed to develop research on process and product innovation, Eureka is an R&D subsidy programme that involves 38 countries, mainly EU members. Each Eureka collaborative research includes research partners from at least two countries. The Eureka subsidised research partners are mainly firms, research centres and universities. Between 1985 and 2004, $8,520$ research partners were involved in the Eureka programme.[6] This Eureka network includes $4,698$ European firms and $1,937$ other European partners. The financial health of firm is a key criterion in the allocation of Eureka's subsidies. The Eureka agencies target growing firms with good expectations of

[6] The information on the number of Eureka partners comes from the Eureka website (www.eureka.be).

survival. Firms that request subsidies but do not get them are generally in decline. We call these latter firms in termination cases. The programme supports mainly manufacturing but research in agriculture and services are also funded. In table 1, we see that Eureka in France covers one third of the 99 NACE [7] two-digit industries.

[Table 1 about here]

The organisation of Eureka is decentralised. The allocation of funds takes place at the country level, not at the European level. In other words, the providers of public subsidies are the national authorities. Every year, each Eureka country chooses the level of public funds to be devoted to Eureka.

The duration of the Eureka subsidy varies between 1 and 8 years, running, on average, for about 3 and a half years. The Eureka agencies analyse the progress of the collaborative research for monitoring purposes. The Eureka subsidy is a partial support that can reach 50% of the firm's R&D expenditures. It can take the form of an interest-free loan. The loan does not have to be repaid if the collaborative research fails. However, this Eureka rule does not apply to French partners.

3.2 Accurate evaluation[8]

Although many governments implement R&D programmes around the world, the design of public R&D subsidies for process and product innovations raises a political debate. This is mainly because these commercial programmes are not protected against moral hazard. Since public subsidies provide a less expensive source of capital than any other, there are two sets of recipients of R&D subsidies: firms able to support research without the subsidies; and firms not eligible for capital from other investors, i.e. firms that could not undertake research without public funds.

The controversy is linked to the fact that the providers of public subsidies are unlikely to be able to disentangle the two sets of firms requesting R&D subsidies. Therefore, they are unable to protect themselves against potential opportunistic behaviour.

Wallsten (2000) argues that the public agencies should not fund firms on a criterion of commercial expectations. It is misleading because the R&D proposals with the greater commercial expectations present high private returns

[7]NACE is a classi?cation of economic activities in Europe. The NACE classification is available from the EUROSTAT website: http://ec.europa.eu/eurostat/ramon.

[8]Wallsten (2000) is the main source of this subsection.

and would be pursued anyway. Instead, the government agencies should select the best proposals associated with a good level of social returns and not profitable on a private basis. Given the nature of the latter proposals, public subsidies are the only source of research financing for them. With governmental support, these socially profitable projects can also become profitable from a private point of view.

The allocation of R&D subsidies could be based on the expected social returns rather than on the expected private ones. However, estimation of the expected social returns is not simple because of the existence and the magnitude of R&D spillovers. Therefore, the government agencies cannot easily distinguish *ex-ante* the firms that would undertake the research without the public subsidies and those that would not.

The presence and magnitude of the "crowding-out" on R&D expenditures after public support can help to signal this distinction *ex-post*. By investigating the extent to which Eureka subsidies affect firms' R&D expenditures, we attempt in the article to explore *ex-post* the ability of Eureka agencies to select the firms that will benefit the most from subsidies. Their ability to do this affects the effciency of the programme as well as its impact on the firms' performance and the diffusion of R&D spillovers in the economy.

4 Data description and empirical methodology

4.1 Data description

Our database comes from the merger of the Eureka database and Amadeus. The Eureka database (1998-2005) includes the name and identification (SIREN) code of all the Eureka research partners and some firms in termination cases.[9] The set of firms in termination cases that we worked with is a sample of the population of firms in termination cases. The whole population is not available because the Eureka agencies do not systematically keep the request form when a subsidy request is ruled out.

Amadeus is a pan-European database (1997-2006) [10] of the annual accounts of EU public and private firms. For several European countries Amadeus is a survey, but in France it is a census that includes key variables such as the value added, exports and R&D expenditures.

We used the SIREN code to merge the Eureka database with Amadeus. The resulting database includes 226 Eureka firms; employment is available

[9] The Eureka database was provided by the Eureka secretariat in Brussels.

[10] We used the version of Amadeus covering 1997 to 2006.

for 169 of them. Value added is deflated by the price index of EU Klems. The capital is annually deflated by the price index of the gross formation of fixed capital from INSEE. The GDP of the French departments comes from Eurostat.

A distinction is made between the R&D expenditures on the balance sheet of the firms and the R&D expenditures on the income statement. Our database includes the intangible fixed assets (proxy for the R&D expenditures of the balance sheet) but we have no data on the R&D expenditures on the income statement. Those expenditures are accounted for in the income statement because they do not generate value (knowledge). They then affect the profit and loss of the firm. The R&D expenditures creating value which increase the R&D stock of the firm is seen as an asset, and accounted for in the balance sheet.

4.2 Empirical methodology

4.2.1 Control group

Our control group is a group of firms with the same characteristics as the Eureka firms at the beginning of the Eureka programme, which did not get subsidies. This control group was generated by one-to-one propensity score matching. Specific requirements on the matched firms' location and industry were added to increase the validity of the matching procedure. The matching picks up the counterfactuals in the same NUTS 3 regions[11] (called departments in France) as the Eureka firms and in the same NACE two-digit industries. Firms in NACE four-digit industries were excluded so as not to capture R&D spillovers which might benefit firms selling similar goods or services as the Eureka firms.

By picking matched firms in similar industries located in the same department as the subsidised firm, we attempted to assess the endogeneity issue linked to national subsidies. This endogeneity comes from the fact that it is the French government that chooses the French Eureka firms in specific industries located in selected high density and backward areas. [12] Propensity score matching without additional requirements cannot correct this kind of endogeneity. In that case, the method only corrects the endogeneity associated with the previous R&D activities of the subsidised firms

[11]The Nomenclature of Territorial Units for Statistics (NUTS) in Europe is available on the EUROSTAT website: http://ec.europa.eu/eurostat/ramon/nuts.

[12]Here, we assume that all matched firms know about the programme since they are located in Eureka departments.

(see the balancing assumption that we present below).[13]

To build the matched control group, one-to-one nearest neighbour matching with the Mahalonabis distance was performed without replacement. The 87 subsidised firms and the 87 matched firms of the difference-in-differences (DD) analysis are on the common support region where the propensity score distribution of the Eureka group and the control group overlap (Heckman et al., 1997). We assume that the conditional independence assumption of matching is satisfied. This means that we assume that we have taken account of all the firms' characteristics that determine the treatment (i.e. the allocation of the Eureka subsidies). This in turn implies that the treatment is the only factor affecting the outcome gap between the treated firms and their matched counterfactuals (Caliendo & Kopeinig, 2008).

The quality of the propensity score matching relies on the balancing assumption, according to which the matching procedure balances the distribution of the firms' characteristics affecting the treatment in the Eureka and matched firm groups. It means that the characteristics of the treated and untreated firms are the same during the pre-treatment period.

Given that the balancing tests used in the literature can yield different conclusions about the balancing ability of matching (Smith & Todd, 2005), we used two types of tests. We first performed univariate t-tests of the difference in means for each of the seven variables used in the matching (i.e. the seven firm characteristics). Next, we performed the multivariate Hotelling T^2 test, comparing the means of all the variables simultaneously. Table 2 shows that the matching was close. The univariate t-tests show that, for each of the seven variables, the means were similar in the treated and matched groups during the pre-treatment year. The Hotelling T^2 test does not suggest any imbalance neither. The assumption that the two vectors of seven means are equal is not rejected.

[Table 2 about here]

Since the subsidy and pre-subsidy periods are not the same for all Eureka firms, we estimated the propensity score for each pre-treatment period. Following Arnold and Javorcik (2009), we applied our matching procedure year by year. In addition, we computed TFP estimates by NACE three-digit industries using Levinsohn and Petrin (2003) methodology.[14] We used the

[13] The endogeneity associated with the previous R&D activities is corrected since the Eureka firms and the matched firms have the same R&D expenditures before the subsidies.

[14] The semi-parametric approach of Levinsohn and Petrin (2003) corrects the simultaneity bias in the production function estimation linked to input choices (VanBeveren, 2007).

value-added TFP version instead of the sales TFP version because it fits our topic on R&D better.

4.2.2 Firm heterogeneity

The literature on trade points out that firm heterogeneity is a key issue in the understanding of the firms' performance and structure. Starting from this literature, we believe that R&D subsidies may not have the same effect on the productivity of heterogeneous firms. Following the theory presented above, we expect them to have a greater effect on less efficient firms than on more efficient ones. This can be linked to knowledge flows between partners within a joint research project, and to what the innovation literature calls the complexity of an R&D project.[15] More precisely, less efficient firms have more space for innovation. Being far from the technological frontier, their projects are less advanced. They can also take advantage of the R&D spillovers generated by their research partners, as suggested by Cassiman and Veugelers (2002).

To test whether the impact of R&D subsidies differs across heterogeneous firms, we compute the initial distance-to-the-frontier-firm where the frontier firm of the NACE four-digit industry j is the firm with the highest TFP. TFP_{ij} is the exponential of tfp_{ij} used in DD models (Konings & Vandenbussche, 2008). The initial distance-to-the-frontier-firm for the firm i is defined as the TFP of the firm i[16] divided by the TFP of the frontier firm of the NACE four-digit industry j. Thus the distance lies within $[0;1]$.

$$DISTANCE_{ijT} = \frac{TFP_{ijT}}{Max_j TFP_{jT}} \tag{6}$$

A distance of 1 means that the firm i is the frontier firm in the NACE four-digit industry. The closer to zero the distance is, the less efficient the firm is compared to the frontier firm. The distance-to-the-frontier index is estimated using all the firms in the Amadeus database belonging to the Eureka industries (i.e. out of sample). This normalised distance is computed before the Eureka subsidies came into play in year T.

[15] See Reinganum (1989) for a survey of the literature on models linking the probability of innovation and R&D complexity.

[16] The firm i is both the Eureka firm and the matched firm.

4.2.3 Difference-in-differences

Using the DD technique, we investigated the way in which two sets of similar firms developed after one set received public subsidies to invest and collaborate in R&D and the other set did not. Our DD specifications estimate the gap in TFP and labour productivity. Specifications are also performed on other outcomes such as R&D expenditures, capital and employment. The DD equation for TFP with firm and year fixed effects is the following:

$$tfp_{it} = \alpha + \beta_1 SUBS_{it} + \beta_2 AFTSUBS_{it} + \beta_3 YEAR-DUMMIES_t + \gamma_i + \epsilon_{it} \quad (7)$$

A dummy variable, $SUBS$, was created to identify the years when the firm got public support through the Eureka programme. The dummy variable takes the value 1 in the years of the subsidy and 0 in the years before and after the subsidy for the Eureka firm. The dummy always takes the value 0 for the firms in the control group. Since R&D expenditures are sunk costs that need time to bear fruit, we expected to find a delay between the investment of the public subsidy in collaborative R&D and any effect on productivity. The $AFTSUBS$ variable captures this delayed effect. $AFTSUBS$ takes the value 1 in the years after the R&D subsidy and 0 in the years before and during the subsidy for the Eureka firm. It is always 0 for the matched firms. $SUBS$ and $AFTSUBS$ are key variables in the DD specifications. We believe that they can identify the causal relationship between the subsidies for the collaborative R&D and productivity (i.e. they estimate the change in productivity due to the subsidies). Firm fixed effects were included in the DD specifications on the panel data because time-invariant firm characteristics (such as the industry and the department) matter. In addition, we controlled for the Order 1 autoregressive process ($AR(1)$) of the error terms. This process can influence the results because the increasing or decreasing trend of the firm's productivity may explain the difference in outcome between the treated firms and the matched counterfactuals.

5 Attracting R&D subsidies

5.1 Geographical pattern and summary statistics

An analysis of the characteristics of the Eureka firms is useful to learn more about the rules of the Eureka subsidies. A map, concentration indexes and some descriptive statistics are presented in figure 5 and tables $3-4$. Concentration indexes are used in geographical economics and in industrial organisation to study the concentration of an industry. Here, we assume that all Eureka firms belong to the Eureka "industry" whose concentration is under scrutiny. To study the Eureka geographical pattern, we built a map showing the location quotients in 2006. France consists of 94 departments. The map (Figure 5) shows clearly that the French Eureka firms are located in high density and backward areas.

[Figure 5 about here]

The Eureka location quotient is above 1 in 32% of the departments and five areas of concentration emerge: Ile-de-France, the North-East (Alsace, Meurthe-et-Moselle), the South-East (Ain, Isère, Alpes Maritime), the North-West (Finistère, Mayenne) and the Central South-West (Indre, Puy-de-Dôme, Landes). More precisely, the Eureka firms are mainly concentrated in Puy-de-Dôme, Hauts-de-Seine, Yvelines, Charente and Creuse. The location quotient for each of these departments is over 3.

The density of concentration areas is mixed.[17] Some of the Eureka firms are located in the high-density areas of Ile-de-France and Alpes-Maritimes, but others are found in backward areas, in particular in the Central South-West. This concentration in backward areas seems to be linked to the Eureka rules. Indeed, the concentration in those areas suggests that the French R&D subsidy policy aims at improving the competitiveness of regions with low density.

We also built plant-based and employment-based concentration indexes ($\hat{\gamma}_{MS}$ and $\hat{\gamma}_{EG}$) for 2006. The first index was proposed by Maurel and Sedillot (1999), and the second by Ellison and Glaeser (1997). The indexes for the Eureka firms (table 3) show that the locations of any two Eureka firms are positively correlated. Tests on the variance of the concentration indexes show that they are significant at the 95% confidence level (Maurel & Sedillot, 1999). However given the magnitude of the indexes, this correlation is weak. Moreover, the difference between the estimators is large. The plant-based estimator $\hat{\gamma}_{MS}$ is four times greater than the employment-based estimator $\hat{\gamma}_{EG}$. Such facts show that the French Eureka plants are heterogeneous in terms of employment (Lafourcade & Mion, 2007).

[Table 3 about here]

[17] For the department density, we use the GDP per capita of the departments, which is available on the Eurostat website:
http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home.

Table 4 presents descriptive statistics for the period $1998 - 2005$. The first column concerns all French firms in similar NACE four-digit industries to the Eureka firms, and located in the Eureka departments. The last two columns concern the Eureka firms and the firms in termination cases. We see that the Eureka firms are on average large firms, with a high level of value added. The magnitude of the standard errors for employment confirms that the Eureka firms are not homogeneous in terms of employment (as shown in table 3). Moreover, the Eureka firms and the firms in termination cases are, on average, located in areas with a lower GDP than other firms. The firms in termination cases usually are large firms with a lower level of value added than the Eureka firms. This fact is linked to the selection procedure for subsidising firms: firms in decline are not supported.

[Table 4 about here]

5.2 Probability of attracting Eureka R&D subsidies

Tables 5 and 6 show the results of logit models on firms' probability of attracting Eureka subsidies, and hence the characteristics of the firms getting the subsidies. The propensity score for matching is derived from these models and allowed us to select the matched control group. Here, we compare the Eureka firms with the firms in close NACE four-digit industries located in the same departments during the pre-treatment period. We also compare the Eureka firms with the firms in termination cases. For the Eureka firms, the binary outcome of the logit model is worth 1 in the first year of the subsidy and 0 in the years before the subsidy. Data on subsidised firms is dropped after the first year of the subsidy because having a dependent variable equal to 0 means that the firm has never been subsidised. The outcome is always 0 for unsubsidised firms. The covariates are lagged by a year so that we can focus on the pre-treatment year. During the selection process, the R&D proposal and financial health of firms requesting Eureka subsidies are scrutinised. As the selection of Eureka firms can be endogenous with their R&D expenditures, it is likely that the better a firm knows the market and performs in it, the better its R&D proposal will be.

In selecting firms for subsidies it is likely that the Eureka agencies look at size (employment) and performance indicators such as longevity (i.e. age, a proxy for firm's experience), productivity (seen as a measure of technology), the growth rate of capital investment (a proxy for the firm's growth trend), credit constraints (loans on sales) and the firm's ability to sell products beyond the borders of the domestic market. Employment can also be seen as a proxy of the firm's lobbying skills. Large firms in France are more likely than smaller firms to be able to put the authorities under pressure for subsidies.

We evaluated binomial logit models. Another way to proceed would have been to perform a multinomial logit. However this is not meaningful given the size of the control group of firms in termination cases relative to the size of the group of firms in closed industries.

The logit specifications include sector and department dummies because it is expected that industries and locations affect the selection of the subsidized firms. First, the map (figure 5) on the concentration of the Eureka firms suggests that the geographical location of subsidised firms is not random.[18] The location is driven by forces related to the rules of the programme. As the Eureka programme in France is supported by the French authorities, we expect the R&D subsidies to be part of a policy helping relatively good firms to grow by improving their technology. Due to regional European policy, it is also likely that the Eureka agencies get incentives to subsidise firms located in areas of low economic activity, and this is confirmed on the map. Next, it is likely that firms of some specific industries have a higher probability to get R&D subisidies than firms operating in other industries.

In Table 5, the results of the logit models for the Eureka firms and firms that did not request the Eureka subsidies show that older firms and those with a larger number of employees are more likely to be subsidised. Firms with a high TFP also have a greater probability of receiving subsidies. The TFP variable is significant at the 5% level. In addition, a higher exports-to-sales ratio results in greater attractiveness to the Eureka agencies. A positive growth in capital also increases the probability of receiving subsidies (see column 4).

[Table 5 about here]

The sector and department dummies are omitted from the model described in column 1 of table 5. The introduction of department dummies changes the positive and insignificant coefficient of TFP to a positive and significant one in column 2. This shows that the Eureka firms are productive firms in less productive departments. Column 3 with industry dummies and no department dummies gives results similar to the first model.

The results in table 6 show that, before the subsidies, the Eureka firms had a better productivity trend than firms in termination cases. The growth

[18]The assumption that the location of Eureka firms is random (as far as the location of firms can be random (see Ellison and Glaeser (1997)) is rejected.

in TFP is always positive (around 0.17) and significant. During the pre-subsidy year, firms in termination cases are similar to the Eureka firms except for their growth in TFP and exports-to sales ratios. When the sector and department dummies were excluded, growth in TFP and the exports-to-sales ratios were both positive and significant (column 1). With sector dummies or department dummies, the exports-to-sales ratio becomes negative and insignificant (columns 2 and 3). This indicates that the Eureka firms are located in departments and industries that exported more than the firms in termination cases. The exports-to-sales ratio become insignificant when both the sectors and the departments are controlled (column 4). Therefore, table 6 suggests that the Eureka firms were on a faster growth track than the firms in termination cases. In addition, the descriptive statistics in table 4 concerning data on the whole time-span shows that the firms in termination cases were unable to improve their value added. This reflects the Eureka rule of supporting firms with a potential for growth. Given this fact, we will not provide DD results for the firms in termination cases.

[Table 6 about here]

6 Results: evaluating the effects of the R&D subsidies

We performed DD specifications on various outcomes such as employment, capital, and loans on sales to investigate the extent to which the structure of the Eureka firms differed before and after the subsidies. We also assessed the issue of the potential "crowding-out" of R&D activities. The origin of this effect can be crucial for the causal relationship between the Eureka subsidies and firm productivity. Here the "crowding-out effect" was estimated through equations on intangible fixed assets (as a proxy for R&D expenditures). To study the relationship between the subsidies and firm productivity, we performed DD analysis on TFP and labour productivity (taken as the log of the value added per worker). Moreover, we allowed firm heterogeneity. After matching, we corrected for the $AR(1)$ process of error terms in the DD specifications. In doing so, we wanted to ensure that the outcome varies due to the R&D subsidies rather than due to the growing or decreasing trend of Eureka firms. In previous papers on the evaluation of R&D subsidies using the DD approach (whether or not combined with matching), the serial correlation of error terms was not tested.[19]

[19] We are able to test autocorrelation since we have panel data.

6.1 Restructuring and effect on the private R&D expenditure

The first outcomes of interest are employment, capital, R&D expenditures, average wage[20] and loans normalised by sales (the proxy for the firm's credit constraints). In tables 7 and 8, the only significant variables are for the growth in the log of the average wage. Both $SUBS$ and $AFTSUBS$ variables are negative and significant. This finding shows that from the beginning of the R&D subsidies, the Eureka firms have a disadvantage of around 18.5% in terms of growth in average wage. This suggests that the matched firms upgrade their skills more quickly than the subsidised firms. There is no evidence for a link between the Eureka subsidies and employment, capital, R&D expenditures or credit constraints. In other words, we did not find any evidence of restructuring.

[Table 7 about here]

[Table 8 about here]

A particular feature of the analysis is that the subsidised firms did not seem to invest more in R&D. Correcting for the first order autocorrelation, the R&D expenditures were the same for the subsidised and the matched firms. This might indicate that the public subsidies "crowded out" private R&D expenditures, i.e. they are substitutes. Alternatively it might mean that the R&D subsidies are not used to increase the R&D expenditures shown on the balance sheet (i.e. the expenditures on research whose outcome is an asset for the firm). The subsidies might be used instead to increase the R&D expenditures accounted for in the income statement (i.e. the expenditures on research whose outcome is not an asset for the firm). Due to data limitations, we could not observe this latter type of R&D expenditures.

6.2 R&D subsidies and productivity

The second outcomes of interest are TFP and labour productivity. The DD equations between the Eureka firms and the matched firms show that the coefficient of the $AFTSUBS$ variable is positive and significant (column 1 of table 9). The average Eureka firm experiences a gain in TFP of 15.6% relative to its matched counterfactual. This DD result shows that the difference between the TFP at the beginning and end of the subsidies (i.e. the logarithmic growth rate of TFP) is bigger for the average Eureka firm than

[20] The average wage is defined as the firm's total wage divided by employment.

for its counterfactual. Since the two firms had similar TFPs at the beginning of the subsidies,[21] the average Eureka firm must have a bigger TFP after the subsidies.

The coefficient of the $AFTSUBS$ variable is not significant in the triple difference specifications, i.e. specifications where the dependent variable is the variation in TFP (column 2). These results suggest the improvement in TFP of the average Eureka firm occurs in jumps rather than continuously. On the other hand, the results show little evidence of a subsidy effect on labour productivity for the average Eureka firm (columns 4 and 5).

[Table 9 about here]

6.3 Firm heterogeneity

To allow for firm heterogeneity we computed the initial distance-to-the-frontier-firm (dtf) of the firms. The 87 Eureka firms have scores between 0 and 1. Some 48 Eureka firms had an initial distance below 0.32, 63 had a distance below 0.5 and 5 had a distance of 1. The large fraction of low TFP Eureka firms can be linked to the collaborative nature of the Eureka subsidies. Cassiman and Veugelers (2002) show that less productive firms have a higher propensity to collaborate in order to capture information flows coming from their research partners. In addition, the average initial distance of the Eureka firms was 0.32, with a standard deviation of 0.31. This means that the frontier firm (the most efficient firm, subsidised or not) in a Eureka NACE four-digit industry was three times more productive than the average Eureka firm.

Controlling for firm heterogeneity in column 3 of table 9 shows that the AFTSUBS variable still positive (0.35) and becomes more significant while the interaction between AFTSUBS and the initial distance is negative (−0.61) and significant. This finding suggests that firm heterogeneity matters i.e. the overall delayed effect of the subsidies depends on the initial productivity. For the average Eureka firm, the overall impact of the subsidies on its TFP is 15.6% after four yearsa. All 72 Eureka firms with an initial distance below than 0.57 show an improvement in their TFP. The least efficient firm in a Eureka NACE four-digit industry (zero initial distance) has an improvement in TFP of 35% relative to its counterfactual. The most efficient one has a disadvantage of 26.% relative to its matched firm. We find little evidence of the subsidy effect on labour productivity for the aver-

[21] See table 4 on the balancing assumption.

age Eureka firm (columns 4 and 5). However, column 6, which includes the initial distance, shows that firm heterogeneity is a key point to this outcome.

The heterogeneous impact of the Eureka R&D subsidies on firms is a striking feature. It can be associated with R&D spillovers. It might be that the further the Eureka firm is from the frontier, the larger are the spillovers. More precisely, it is not likely that the "assortative matching" is so strong that the "very laggard firms" only collaborate with other "very laggard firms", while the firms at the frontier collaborate only with other firms at the frontier. On average, the likelihood that a "very laggard firm" collaborates with a firm closer to the frontier is higher than the likelihood that this firm collaborates with another "very laggard firm". Hence, it might be that a Eureka firm at the frontier experiences lower productivity gains than its matched firm, since it spends time explaining how to innovate to its research partners.

As the Eureka R&D subsidies are not proportional to the firms' size, it may be that the heterogeneous Eureka impact is also linked to size of the highly productive firms. Given that the Eureka firms the closest to the frontier are large firms,[22] it is possible that those firms do not get an R&D subsidies large enough to allow them to innovate, while small or medium-sized firms located at the same small initial distance could innovate with the same level of subsidy. Therefore, those highly productive are characterised by their size and the tougher innovation they face being close to the frontier. In the following part on the robustness checks, the link between productivity and initial size is investigated.

Furthermore, the lower gains in productivity of the frontier Eureka firms (relative to their matched firms) can come from the fact that they take more time to innovate. It is possible that research conducted by a frontier firm within a Eureka joint venture is part of a long-run R&D project whose the effect on productivity will appear later on.[23] For strategic reasons, only part of this project is shared with the Eureka partners.

Finally, it is possible that the highly productive firms in the control group became more productive because they conducted R&D mainly aimed at decreasing their marginal costs, whereas the highly productive Eureka firms conducted R&D to increase the variety of their products on the market.

[22] The seven Eureka firms closest to the frontier had more than 40 employees at the beginning of the subsidies.

[23] We estimate the impact of the R&D subsidies on a period up to four years after the Eureka research. Beyond those four years, it is more complicated to assess a causal impact of the subsidies.

6.4 Robustness checks

As a first robustness check, the heterogeneous impact of the Eureka subsidies on other outcomes was tested in Table 10. In particular, column 2 shows such a impact on capital. The coefficient of the SUBS variable is negative and significant while its interaction with the initial distance from the technology frontier is positive. This shows that, on average, the Eureka firms invested less in capital during the subsidised period than the matched firms.

Interestingly, the positive coefficient of the interaction term shows that the highly productive firms invested more in capital than their matched firms. If their increase in capital is due to an increase in R&D capital, the result suggests the highly productive firms involved in research joint venture face more difficulties or take more time to innovate than their matched firms. On the other side, there is little evidence of a heterogeneous impact on employment, R&D expenditures, average wage, or credit constraints.

[Table 10 about here]

Next for the second robustness check, we turn to the average impact of the Eureka subsidies on different periods. Column 1 of table 11 indicates a gain in TFP of 16.5% one year after the Eureka subsidies,[24] a gain of 16.4% after two years and a gain of 16.3% after three years. The gain of 15.6% obtained in column 1 of table 9 comes out after 4 years. Those results lend support to our empirical analysis.

[Table 11 about here]

Our third robustness check examines the relationship between TFP and the initial size of the firm. The results in column 2 of table 11 suggest that the effect of the subsidies on TFP does not differ according to firm size since the interaction between the $AFTSUBS$ variable and the initial size is insignificant. Nevertheless as mentioned in the previous section, there are no small or medium Eureka firms close to the technology frontier in the sample. Therefore, the possibility that the highly productive Eureka firms do not get enough subsidies relative to their size cannot be excluded.

Finally in column 3 of table 11 we test spatial autocorrelation in the sense that productivity shocks of one firm in a department can affect the productivity of the firms located in the same department. The results controlling for spatial autocorrelation prove to be similar to the previous results

[24]The large magnitude of the gain in TFP can be attributed to the fact that we use the added value version of the TFP fucntion instead of the sales version.

on firm heterogeneity (column 3 of table 9). They then show that spatial autocorrelation does not matter in our case.

7 Discussion: gain in productivity and effect on private R&D expenditures

An important result in our empirical analysis that needs more discussion is the fact that we observe an increase in average TFP for Eureka firms, even if their R&D expenditures are similar to those of the control group. Two explanations can be provided. The first is that our data only considers expenditures from the balance sheet. It could be however the subsidies received by Eureka firms are accounted in their income statement, which we do not have access to. The second is due to spillover effect, where by collaborating with others firms, Eureka firms increase their productivity more than the control group.

Another point to discuss is the "crowding-out" of R&D expenditures. The results show that during the subsidized period, the Eureka firms and the control group that do not get R&D subsidies have similar R&D expenditures. This fact show that the Eureka firms decrease their private R&D expenditures and suggests that those private expenditures are "crowded out" by the subsidies. In the case where the "crowding-out effect" is associated with opportunism, the increase in average TFP cannot be attributed to the Eureka subsidies because the subsidized firms are firms able to conduct R&D and increase productivity without subsidies. In other words, a "crowding-out effect" related to opportunism shows that the Eureka agencies fail to select the proposals that will not be pursued otherwise. This affects the efficiency of the Eureka program.

Nevertheless, a "crowding-out" of private R&D expenditures can have several other explanations. First, it can be related to the sharing of R&D expenditures between the Eureka firms. The collaboration in R&D deletes the duplication and overlaps (Katz, 1986). The Eureka firms then decrease their R&D private expenditures. Second, the "crowding-out" can also show that the subsidized firms delay the financing of their own R&D to the period after the subsidies. The subsidies thus ensure them to conduct research also beyond the subsidized years (Wallsten, 2000). Third, it is also possible that a good selection of the Eureka firms explains the results. The matched firms find the support of other investors and undertake R&D projects. This means that the Eureka agencies have a proper ability of choosing the R&D proposals that will not be undertaken without the governmental subsidies. Finally, as mentioned above data only includes the R&D expenditures accounted in the balance sheet. It can be therefore that the R&D expenditures from the income statement are higher for the Eureka firms although their R&D expenditures from the balance sheet are similar to the control group.

Due to lack of data, we can neither study the relationship between the R&D subsidies and R&D expenditures from the income statement nor to test the sharing assumption and the assumption following which the Eureka firms keep private funds during the subsidies to be able to finance their private R&D afterwards. Consequently, we cannot exclude that there is a "crowding-out effect" associated with opportunism. In order to shrink this kind of effect, the Eureka programme could be more protected against moral hazard by a strengthening of monitoring.

Beside a lack of data mentioned above, our study has three major limitations. First, we do not investigate the impact of the Eureka program on R&D spillovers and social welfare. Second, we do not know if the Eureka firms and the firms in the control group get other kinds of subsidies. Third, as Lerner (1999), our single program analysis does not allow us to compare the Eureka program with other R&D subsidies programmes based on different rules. Concerning the effect of Eureka program in Europe, our interest for a single European country does not allow to study the difference between countries and therefore restricts the discussion on the European geographical disparities associated with the Eureka programme.

8 Concluding remarks

Governments set up R&D programmes to increase the knowledge creation of firms, competing in an evermore integrated and global economic framework. This paper endeavors to deepen our understanding of R&D subsidies on firm productivity. Previous literature have mainly investigated the average effect of R&D subsidy on firm performance. However, the impact of subsidies on heterogeneous firms has never been investigated. In particular, as pointed out by the trade literature, firm heterogeneity can be crucial to understand the performance of firms. The main contribution of this paper is thus to propose both a theoretical and empirical model to analyst the impact of R&D subsidies on heterogeneous firms and namely their productivity.

The theoretical model provides an answer as to how an R&D subsidy makes a firm develops a new technology faster. The model is an extension to the model of the Miyagiwa and Ohno model (1995) and shows that a firm getting a subsidy for collaborative R&D speeds up the technology adoption and becomes more productive. The earlier adoption is associated with R&D spillovers and a decrease in the innovation cost. It is also found that firm heterogeneity matters. The model shows that a subsidized firm adopts the new technology faster if it is lowly productive than if it were highly productive. Being located far from the technology frontier, a lowly productive firm can more easily innovate than a highly productive firm.

This paper also provides an empirical analysis to examine the impact of the European Eureka program of public R&D subsidies on firm performance, which corroborates the theory. More important, the empirical model examines how R&D subsidies affect the performance of heterogeneous firms. We use a unique database on the French Eureka firms. Other firm data such as added value, exports and R&D expenditures were obtained using the Amadeus database on the firms' balance sheets. Difference-in-differences technique is used to assess the role of R&D subsidies on productivity and other firm performance measures like employment and capital. The potential "crowding-out" of private R&D expenditures is also investigated. This effect is crucial to assess the causal relationship between the subsidies and productivity. The results suggest that, on average, the TFP of the subsidized firms is higher of around 15% towards the end of the 4-year subsidy period relative to the matched control group. The empirical results also suggest that the subsidized firms raise less their wages in comparison to the matched control firms. There is little evidence about a role of R&D subsidies on employment, capital, R&D expenditures and credit constraints.

Controlling for firm heterogeneity, we see that the R&D subsidy policy creates productivity gains for the less efficient subsidized firms. Those firms become more productive than their matched firm in terms of both labour productivity and TFP. It is not the case for the most efficient firms that become less productive than their matched firm.

This paper shows that firm heterogeneity brings new insight on the effects of R&D subsidies on firm-level productivity. Indeed, the results suggest that investigating the average effect of R&D subsidies on firm performance is not sufficient, and studying firm heterogeneity is important. It is likely that firm heterogeneity will attract more and more attention in the future research on public expenditures.

References

Arnold, M. J., & Javorcik, B. S. (2009). Gifted Kids or Pushy Parents? Foreign Direct Investment and Plant Productivity in Indonesia. *Journal of International Economics*, *79*(1), 42-53.

Baldwin, R. E., & Robert-Nicoud, F. (2007). Entry and Asymmetric Lobbying: Why Governments Pick Losers. *Journal of the European Economic Association*, *5*, 1064-1093.

Baltagi, B. H., & Wu, P. X. (1999). Unequally Spaced Panel Data Regressions With Ar(1) Disturbances. *Econometric Theory*, *15*, 814-823.

Benfratello, L., & Sembenelli, A. (2002). Research Joint Ventures and Firm Level Performance. *Research Policy*, *31*(4), 493-507.

Bernard, A., & Jensen, B. (1995). Exporters, Jobs, and Wages in U.S. Manufacturing : 1976-1987. *Brookings Papers on Economic Activity: Microeconomics*, *1995*, 67-119.

Boucekkine, R., Saglam, C., & Vallée, T. (2004). Technology Adoption Under Embodiment: A Two−Stage Optimal Control Approach. *Macroeconomic Dynamics*, *8*(02), 250-271.

Caliendo, M., & Kopeinig, S. (2008). Some Practical Guidance for the Implementation of Propensity Score Matching. *Journal of Economic Surveys*, *22(1)*, 31-72.

Cassiman, B., & Veugelers, R. (2002). R&D Cooperation and Spillovers: Some Empirical Evidence from Belgium. *American Economic Review*, *92*(4), 1169-1184.

d'Aspremont, C., & Jacquemin, A. (1988). Cooperative and Noncooperative R&D in Duopoly with Spillovers. *American Economic Review*, *78*(5), 1133-37.

Ellison, G., & Glaeser, E. L. (1997). Geographic Concentration in U.S. Manufacturing Industries: a Dartboard Approach. *Journal of Political Economy*, *105*, 889-927.

Heckman, J. J., Ichimura, H., & Todd, P. E. (1997). Matching as an Econometric Evaluation Estimator: Evidence from Evaluating a Job Training Programme. *Review of Economic Studies*, *64*(4), 605-54.

Jaffe, A. B. (1986). Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Value. *American Economic Review*, *76*(5), 984-1001.

Katz, M. L. (1986). An Analysis of Cooperative Research and Development. *RAND Journal of Economics*, *17*(4), 527-543.

Konings, J., & Vandenbussche, H. (2007). Antidumping Protection and Productivity of Domestic Firms: A Firm Level Analysis. *Licos Discussion Paper, KULeuven*.

Konings, J., & Vandenbussche, H. (2008). Heterogeneous Responses of Firms to Trade Protection. *Journal of International Economics*, *76*(2), 371-383.

Lafourcade, M., & Mion, G. (2007). Concentration, Agglomeration and the Size of Plants. *Regional Science and Urban Economics*, *37*, 46-68.

Leahy, D., & Neary, J. P. (1997). Public Policy towards R&D in Oligopolistic Industries. *American Economic Review*, *87*(4), 642-62.

Lerner, J. (1999). The Government as Venture Capitalist: The Long-Run Impact of the SBIR Program. *Journal of Business*, *72*(3), 285-318.

Levinsohn, J., & Petrin, A. (2003). Estimating Production Functions Using Inputs to Control for Unobservables. *Review of Economic Studies*, *70*, 317-341.

Martin, P., Mayer, T., & Mayneris, F. (2008). Public Support to Clusters: A Firm Level Study of French Local Productive Systems [CEPR Discussion Papers]. (7102).

Maurel, F., & Sedillot, B. (1999). A Measure of the Geographic Concentration in French Manufacturing Industries. *Regional Science and Urban Economics*, *29*, 575-604.

Miyagiwa, K., & Ohno, Y. (1995). Closing the Technology Gap under Protection. *American Economic Review*, *85*(4), 755-70.

Reinganum, J. F. (1989). The Timing of Innovation: Research, Development, and Diffusion. In R. Schmalensee & R. Willig (Eds.), *Handbook of Industrial Organization* (Vol. 1, p. 849-908). Elsevier.

Smith, J., & Todd, P. (2005). Rejoinder. *Journal of Econometrics*, *125*, 365-375.

VanBeveren, I. (2007). Total Factor Productivity Estimation: A Practical Review [LICOS Discussion Papers]. (18207).

Wallsten, S. J. (2000). The Effects of Government-Industry R&D Programs on Private R&D: The Case of the Small Business Innovation Research Program. *RAND Journal of Economics*, *31*(1), 82-100.

Appendix

Figure 1: Optimal adoption date and R&D collaboration

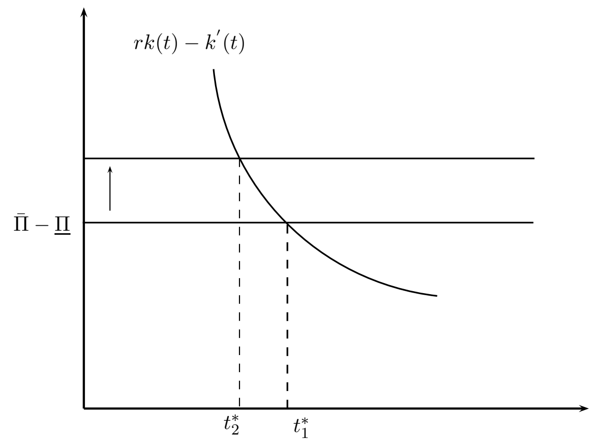


Figure 2: Optimal adoption date and R&D subsidy

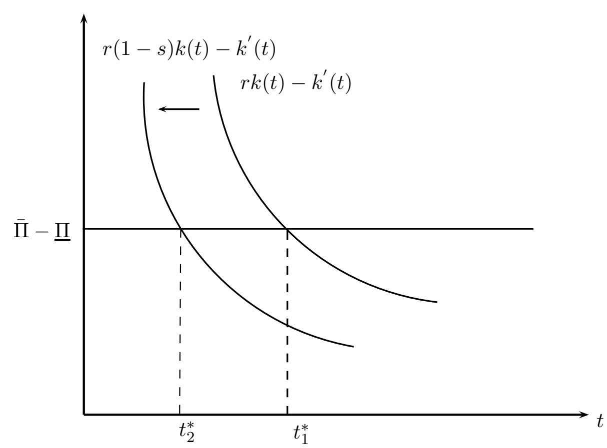


Figure 3: Firm heterogeneity, optimal adoption date and R&D collaboration

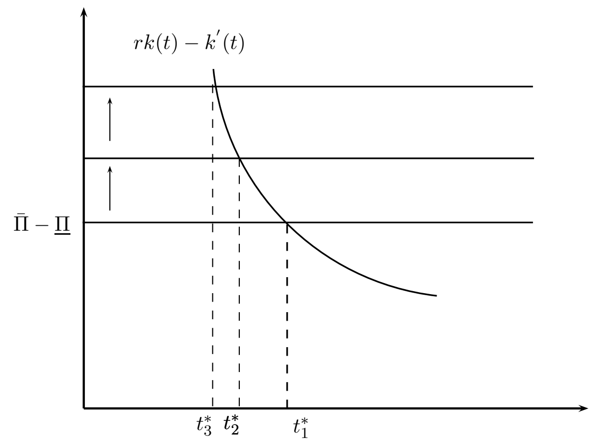
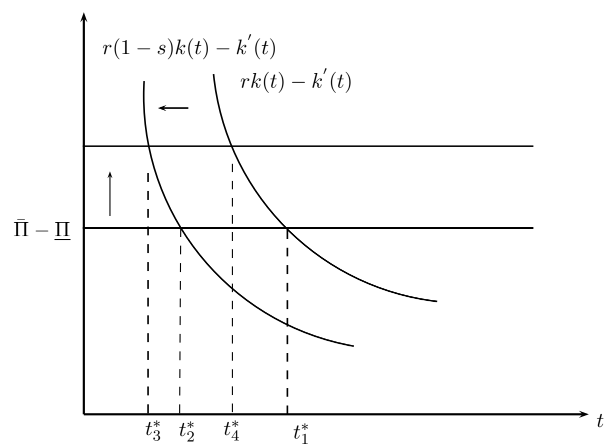


Figure 4: Firm heterogeneity, optimal adoption date and R&D subsidy



Map and location quotients:

The location quotient $Q_{e,l}$ of the Eureka firms located in the French NUTS 3 region (department) l of the map is defined as follow:

$$Q_{e,l} = \frac{n_{e,l}/n_e}{n_l/N}$$

where $n_{e,l}$ is the number of Eureka firms located in department l; n_e is the total number of Eureka firms in France; n_l is the number of firms in department l; and N is the total number of French firms.

Figure 5: Concentration of Eureka firms in 2006

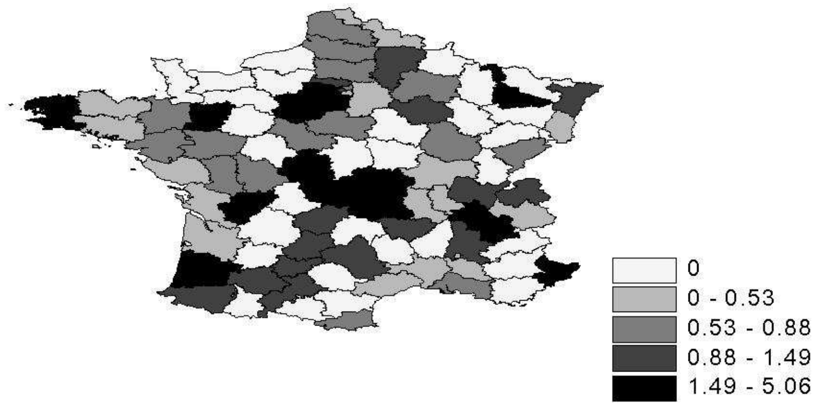


Table 1: NACE two digit Eureka industries‡

NACE	industry	N
01	Agriculture	3
05	Fishing	1
15	Food Products and Beverages	13
17	Textiles	3
18	Wearing Apparel	1
20	Manufacture of Wood	3
21	Manufacture of Paper Products	1
22	Publishing and Printing	2
24	Chemicals	12
25	Rubber and Plastic Products	5
26	Other Non-metallic Mineral Products	1
27	Basic Metals	4
28	Fabricated Metal Products except Machinery and Equipment	7
29	Machinery and Equipment	17
30	Office Machinery and Computers	2
31	Electric Machinery and Apparatus	4
32	Radio, Television and Communication Equipment	14
33	Medical Instruments, Watches and Clocks	18
34	Motor Vehicles, Trailers and Semi-Trailers	3
35	Other Transport Equipment	10
36	Furniture	1
40	Electricity, Gas, Steam and Hot Water Supply	1
45	Construction	4
50	Sale and Repair of Motor Vehicles and Motorcycles	2
51	Wholesale Trade and Commission Trade	4
52	Retail Trade except of Motor Vehicles and Motorcycles	2
63	Supporting and Auxiliary Transport Activities	1
64	Post and Telecommunications	1
67	Activities Auxiliary to Financial Intermediation	1
72	Computer and Related Activities	25
73	Research and Development	17
74	Other Business Activities	26

‡ N is the number of Eureka firms.

Table 2: Balancing tests

	Matched firms	Eureka firms		
Test in means difference	**Mean**	**Mean**	**T-test**	**P-value**
Age_{t-1}	34.07	30.40	0.8963	0.3714
$ln(Employment)_{t-1}$	5.16	5.08	0.2525	0.8010
TFP_{t-1}	4.64	4.56	0.4915	0.6237
ΔTFP	0.02	0.03	-0.1353	0.8925
$ln(Exports/Sales)_{t-1}$	0.23	0.23	-0.1718	0.8638
$ln(Loans/Sales)_{t-1}$	0.01	0.01	-0.1416	0.8876
$\Delta Capital$	0.14	1.16	-1.005	0.3177
N	87	87		
	T^2	**F-stat**	**P-value**	
Hotelling test	2.3080	0.3182	0.9450	

Balancing assumption:

To test the balancing assumption, we first perform univariate t-tests of difference in means between the Eureka firms sample and the matched sample. Those tests show whether the mean of each variable used in matching is the same in both samples. Next, we use the multivariate Hotelling T^2 test, more efficient than the first ones. The latter test compares simultaneously the equality in the mean of the variables. In particular, the Hotelling T^2 test we implement is a t-test of joint equality of the two vectors of means. The vector of means $\in \mathbb{R}^{7\times 1}$. Each row of the vector corresponds to a firm characteristic included in the matching approach.

Table 3: Concentration indexes of Eureka firms‡

	2006	
	$\hat{\gamma}_{MS}$	$\hat{\gamma}_{EG}$
Value	0.0227	0.0044
Standard Deviation	0.0007	0.0009
Number of plants	522,592	522,592
Number of industries	2	2
Number of spatial units	94	94

‡ $\hat{\gamma}_{MS}$ is the plant-based index and $\hat{\gamma}_{EG}$ is the employment-based index. The spatial unit is the department.

Table 4: Summary statistics of key variables for the time-span (1998 – 2005)‡

	Other Firms			Eureka Firms			Firms in T.C.		
Variable	**N**	**Mean**	**Std Dev.**	**N**	**Mean**	**Std Dev.**	**N**	**Mean**	**Std Dev.**
Employment	419,675	44	607	924	1,988	9,347	264	1,326	3,829
Value Added	419,675	2,432	36,792	924	178,958	1,128,493	264	12,916	71,912
Exports	684,375	92,448	2,088,387	1,007	8,968,334	3.32e+07	207	9,996,195	5.37e+07
Department GDP	419,675	160,186	105,093	924	146.130	98,843	264	143,412	97,979

‡ Firms in T.C. are the firms in termination cases. Value added and department GDP are in euros. Std Dev. is the standard deviation and N is the number of observations.

Table 5: Characteristics of firms getting the R&D subsidies: Eureka firms versus firms in same departments and industries‡

	I	*II*	*III*	*IV*
Age_{t-1}	0.002	0.007**	0.002	0.008*
	(0.00)	(0.00)	(0.00)	(0.00)
$ln(Employment)_{t-1}$	0.715***	0.405***	0.710***	0.431***
	(0.06)	(0.06)	(0.06)	(0.06)
TFP_{t-1}	0.063	0.438**	0.048	0.406**
	(0.13)	(0.18)	(0.14)	(0.20)
Δ TFP	0.248	0.341	0.223	0.303
	(0.18)	(0.24)	(0.18)	(0.24)
$ln(Exports/Sales)_{t-1}$	3.680***	1.805***	3.696***	2.083***
	(0.38)	(0.52)	(0.39)	(0.54)
$ln(Loans/Sales)_{t-1}$	0.289	0.184	0.244	0.232
	(0.25)	(0.45)	(0.32)	(0.53)
Δ Capital	0.001***	0.001**	0.001***	0.001***
	(0.00)	(0.00)	(0.00)	(0.00)
Year FE	YES	YES	YES	YES
Department FE	NO	YES	NO	YES
Industry FE	NO	NO	YES	YES
Intercept	-11.122***	-10.414***	-10.847***	-10.631***
	(0.50)	(0.89)	(0.99)	(1.25)
R^2	0.197	0.321	0.215	0.351
N	326,404	235,550	266,085	192,652

‡ Table reports the regressions results of the Logit models where the control group comprises the firms in the Eureka departments operating in the 4 digit NACE industries close to the Eureka ones. FE stands for fixed effects. Standard Errors reported between brackets. Significance level: *p-value<0.10, ** p-value<0.05, *** p-value<0.01.

Table 6: Characteristics of firms getting the R&D subsidies: Eureka firms versus firms in termination Cases‡

	I	*II*	*III*	*IV*
Age_{t-1}	0.001	-0.001	0.001	-0.002
	(0.00)	(0.00)	(0.00)	(0.00)
$ln(Employment)_{t-1}$	-0.023	-0.064	-0.010	-0.064
	(0.03)	(0.05)	(0.05)	(0.06)
TFP_{t-1}	-0.011	0.071	-0.039	0.104
	(0.06)	(0.15)	(0.08)	(0.18)
Δ TFP	0.151**	0.170**	0.151**	0.191**
	(0.06)	(0.08)	(0.07)	(0.08)
$ln(Exports/Sales)_{t-1}$	0.539**	0.743	0.558	0.901*
	(0.32)	(0.39)	(0.45)	(0.55)
$ln(Loans/Sales)_{t-1}$	2.564	2.207	2.487	1.993
	(1.67)	(1.70)	(1.65)	(1.74)
$\Delta Capital$	-0.001	-0.001	-0.001	-0.001
	(0.00)	(0.00)	(0.00)	(0.00)
Year FE	YES	YES	YES	YES
Department FE	NO	YES	NO	YES
Industry FE	NO	NO	YES	YES
Intercept	-1.671***	-0.851	-1.836***	-1.766
	(0.41)	(0.69)	(0.49)	(1.00)
R^2	0.084	0.092	0.103	0.111
N	751	746	718	715

‡ Table reports the regressions results of the Logit models where the control group comprises the firms which request the Eureka subsidy but do not get it. FE stands for fixed effects. Standard Errors reported between brackets. Significance level: *p-value<0.10, ** p-value<0.05, *** p-value<0.01.

Table 7: R&D subsidies and evidence of restructuring: employment, capital and R&D expenditures - Eureka firms versus matched firms[‡]

	1	2	3	4	5	6
	Empl.	Δ Empl.	ln(Capital)	Δ ln(Capital)	ln(R&D Exp.)	Δ ln(R&D Exp.)
SUBS	0.026	0.096	-0.022	-0.012	0.220	-0.210
	(0.50)	(0.10)	(0.07)	(0.10)	(0.25)	(0.33)
AFTSUBS	-0.010	0.037	-0.038	0.006	-0.182	-0.552
	(0.08)	(0.14)	(0.10)	(0.14)	(0.39)	(0.46)
$AR(1)$ coeff.	0.72***	0.39**	0.66***	0.34***	0.56***	0.22***
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Intercept	-0.743***	-1.160***	2.099***	1.829***	-0.839	-2.643
	(0.13)	(0.34)	(0.18)	(0.20)	(0.65)	(1.83)
N	1011	1011	1011	1011	992	980

‡ Table summarizes the regressions results of the DD models where the control group comprises the matched firms. FE stands for fixed effects. The use of the year 1997 to compute the outcome in growth rate explains the no (little) divergence of number of observations between the outcome in level and in growth. Standard Errors reported between brackets. Significance level: *p-value<0.10, ** p-value<0.05, *** p-value<0.01.

Table 8: Evidence of restructuring?: average wage and loans on sales - Eureka firms versus matched firms[‡]

	1	2	3	4
	$ln(Av.Wage)$	$\Delta ln(Av.Wage)$	$ln(Loans/Sales)$	Δ $ln(Loans/Sales)$
SUBS	-0.076	-0.183**	0.005	-0.001
	(0.06)	(0.07)	(0.01)	(0.01)
AFTSUBS	-0.009	-0.188**	-0.005	-0.001
	(0.05)	(0.07)	(0.01)	(0.01)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Intercept	8.314***	0.030	-0.002	-0.001
	(0.02)	(0.05)	(0.01)	(0.001)
N	1182	1180	1183	1107

‡ Table gives the regressions results of the DD models where the control group comprises the matched firms. FE stands for fixed effects. The use of available data for 1997 to compute the outcome in growth rate explains the no (little) divergence of number of observations between the outcome in level and in growth. Standard Errors reported between brackets. Significance level: *p-value<0.10, ** p-value<0.05, *** p-value<0.01.

Table 9: R&D subsidies, productivity and firm heterogeneity - Eureka firms versus matched firms‡

	1	2	3	4	5	6
	tfp	$\Delta\ tfp$	tfp DTF	$ln(Lab.Pr)$	$\Delta ln(Lab.Pr)$	$ln(Lab.Pr)$ DTF
$SUBS$	0.013	0.003	0.088	0.023	-0.045	0.033
	(0.06)	(0.09)	(0.09)	(0.05)	(0.08)	(0.08)
$SUBS * DTF$			-0.118			-0.021
			(0.19)			(0.19)
$AFTSUBS$	0.156*	0.050	0.350**	0.151	0.021	0.280**
	(0.09)	(0.14)	(0.14)	(0.10)	(0.12)	(0.13)
$AFTSUBS * DTF$			-0.611**			-0.479*
			(0.30)			(0.29)
$Capital$				-0.034	-0.058	-0.036
				(0.05)	(0.04)	(0.04)
$AR(1)$ coeff.	0.39*	0.18***			0.05***	
Firm FE	Yes	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
$Intercept$	0.437**	0.101	4.547***	4.477***	4.020**	4.501***
	(0.21)	(0.06)	(0.05)	(0.57)	(2.00)	(0.56)
N	984	857	1158	1158	930	1158

‡ Table shows the regressions results of the DD models where the control group comprises the matched firms. FE stands for fixed effects. DTF is the initial Distance-to-Frontier-Firm. Standard Errors reported between brackets. Significance level: *p-value<0.10, ** p-value<0.05, *** p-value<0.01.

Table 10: Robustness check: restructuring and firm heterogeneity - Eureka firms versus matched firms‡

	1	2	3	4	5
	$Empl$ DTF	$ln(Capital)$ DTF	ln(R&D Exp.) DTF	$ln(Av.Wage)$ DTF	$ln(Loan/Sales)$ DTF
$SUBS$	0.080	-0.174*	0.228	-0.171	0.006
	(0.08)	(0.10)	(0.39)	(0.15)	(0.005)
$SUBS * DTF$	-0.173	0.467**	0.024	0.286	-0.002
	(0.18)	(0.23)	(0.88)	(0.27)	(0.004)
$AFTSUBS$	-0.077	-0.124	0.175	-0.016	0.001
	(0.12)	(0.15)	(0.57)	(0.10)	(0.004)
$AFTSUBS * DTF$	0.256	0.220	-1.211	-0.011	-0.021
	(0.29)	(0.37)	(1.37)	(0.20)	(0.02)
$AR(1)$ coeff.	0.71***	0.66***	0.55***		
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
$Constant$	-0.732***	2.078***	-0.821	8.316***	-0.002
	(0.13)	(0.18)	(0.66)	(0.03)	(0.006)
N	1011	1011	992	1182	1183

‡ DTF is the initial Distance-to-Frontier-Firm. Standard Errors reported between brackets. FE stands for fixed effects. Significance level: *p-value<0.10, ** p-value<0.05, *** p-value<0.01.

Table 11: Robustness check: subsidy effect over time, size effect and spatial autocorrelation - Eureka Firms versus Matched Firms‡

	1 tfp over time	2 tfp INITIAL SIZE	3 tfp spatial autocc.
1 year $AFTSUBS$	0.165*		
	(0.084)		
2 years $AFTSUBS$	0.164*		
	(0.087)		
3 years $AFTSUBS$	0.163*		
	(0.090)		
4 years $AFTSUBS$	0.156*		
	(0.090)		
$SUBS$		0.052	0.087
		(0.063)	(0.77)
$SUBS*$ INITIAL SIZE		-2.24e-04*	
		(1.23e-0)	
$SUBS*DTF$			-0.118
			(0.19)
$AFTSUBS$		0.166*	0.350***
		(0.093)	(0.12)
$AFTSUBS*$ INITIAL SIZE		3.76e-06	
		(2.32e-04)	
$AFTSUBS*DTF$			-0.612*
			(0.32)
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Constant		8.316***	4.547***
		(0.03)	(0.043)
N		984	984
N 1 year after	934		
N 2 years after	964		
N 3 years after	978		
N 4 years after	984		

‡ DTF is the initial Distance-to-Frontier-Firm. $AR(1)$ process is corrected in all columns. Standard Errors reported between brackets. FE stands for fixed effects. Significance level: *p-value<0.10, ** p-value<0.05, *** p-value<0.01.

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